

# Basin-Scale Analysis and Options for Produced Water from Tight-Gas Sand Reservoirs, Uinta Basin, Utah

by David Tabet, Thomas Chidsey, Jr., Craig Morgan, Robert Ressetar, Peter Nielsen, Rebekah Wood, Taylor Boden, Stephanie Carney, Michael Vanden Berg, Stefan Kirby, Hobie Willis, Christian Hardwick, and Richard Emerson; Utah Geological Survey

## Abstract

The production and disposal of water from tight-sand gas reservoirs in the eastern Uinta Basin, Utah, and elsewhere affects the economics of gas resource development and has recently become a topic of much public debate because produced water is the largest-volume waste stream associated with these unconventional gas plays. Environmentally sound management of produced water can be a significant cost associated with gas extraction, so there is an economic incentive to minimize this waste stream and/or reuse produced water in hydrocarbon development, and companies are actively pursuing these technologies. Balancing the water-use needs and produced water disposal requirements associated with shale/tight-sand gas development creates significant material handling challenges to both industry and regulators. These challenges are complicated by an operating environment where many individual producers of varying sizes exist within a field, each with varying water needs and production, and a production timescale of decades for the basin as wells play out and new ones are completed.

About 446 billion cubic feet (Bcf) of gas and 105 million barrels (bbls) of water were produced from the Uinta Basin in 2013. The major tight-gas sand reservoirs in the basin are the Tertiary (Eocene) Wasatch Formation and several formations in the Cretaceous Mesaverde Group. Three major components of our study are: (1) compilation and analysis of past and new information on the thickness, structure, depth, lithology, water quality, and temperature of all aquifer/reservoir units in the basin from the surface (alluvium) down through the Jurassic Glen Canyon Group; (2) mapping of reservoirs/aquifers (structure, thickness, porosity, permeability, lithology) and produced water (quantity, geochemistry, temperature; and (3) statistical analysis of water production quantity and quality to identify and forecast volume trends for each discrete tight-sand gas-producing interval. These components will be incorporated into an evaluation of the existing infrastructure for produced water management/reuse and the recommendations for best management practices of the produced waters in the eastern part of the Uinta Basin.

## Acknowledgments

Major funding for this ongoing research has been provided by the Research Partnership to Secure Energy for America (RPSEA), Sugar Land, Texas: Small Producer Program, for the Utah Geological Survey (UGS) project titled "Basin-Scale Produced Water Management Tools and Options – GIS-Based Models and Statistical Analysis of Shale-Gas/Tight-Sand Reservoirs and Their Produced Water Streams, Uinta Basin, Utah," contract number 11123-08. Remaining funding is provided by the UGS.

Data collection and construction of maps, graphs, and other figures were contributed by Cheryl Gustin of the UGS. Outcrop photos are by Michael Chidsey, Sqwak Productions Inc., and some facility photos were provided by the Utah Division of Oil, Gas, and Mining. A figure of evaporation pond locations came from the Utah Department of Environmental Quality. The poster was designed by Nikki Simon of the UGS.

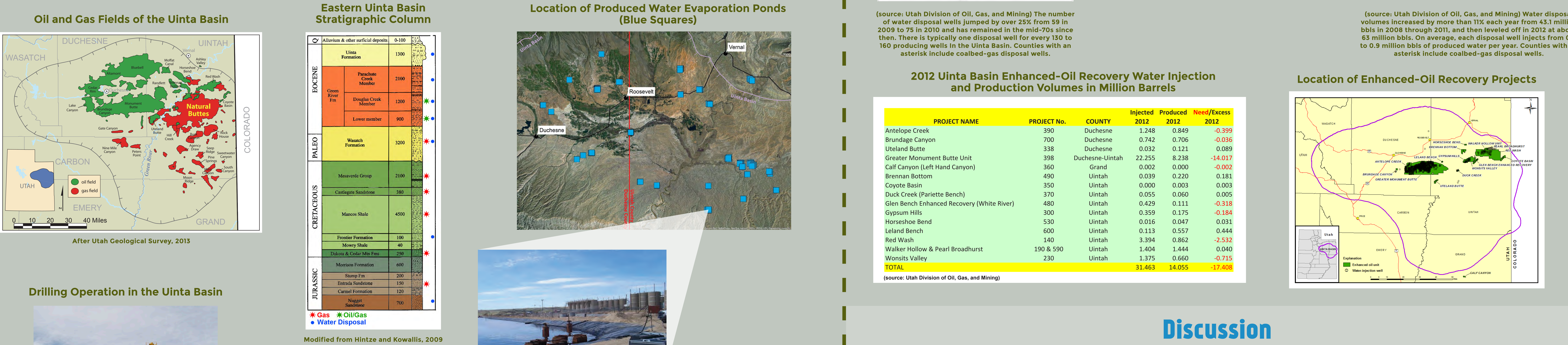
### Disclaimer

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, express or implied, regarding its suitability or a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

# Regional Setting and Overview

## Study Objectives

- Create basin-wide, digital produced water management tools.
- Integrate produced water character, water disposal/reuse, water transport, and groundwater sensitivity factors to allow for quicker and more efficient regulatory and management decisions related to unconventional gas developments.
- Investigate the option of beneficial use of produced water treatment for geothermal heat recovery or power generation.
- Promote maximized produced water reuse, which will minimize use of freshwater in unconventional gas development and production.
- Compile Uinta Basin produced water management practices and recommend best practices.
- Seek to increase protection of critical Uinta Basin alluvial aquifers.



## Discussion

Water management/handling practices in the Uinta Basin vary with the size of the operation. Small oil and gas producers generally depend on outside vendors to haul and dispose of produced water at commercial disposal wells or evaporation ponds. Larger oil and gas producers commonly construct complex, closed-loop, water handling and disposal facilities that allow for the capture and reuse of flow-back formation fracturing fluids, centralized facilities for treatment of produced water, and a series of injection wells or evaporation ponds for water disposal. Water treatments may include settling tanks which skim oil off the top and settle sediments at the base, oil-water separators, hydrocyclones, flotation cells, chemical flocculation of clays, and filtration systems (walnut shell or sock) to provide clean, but saline, water for final disposal.

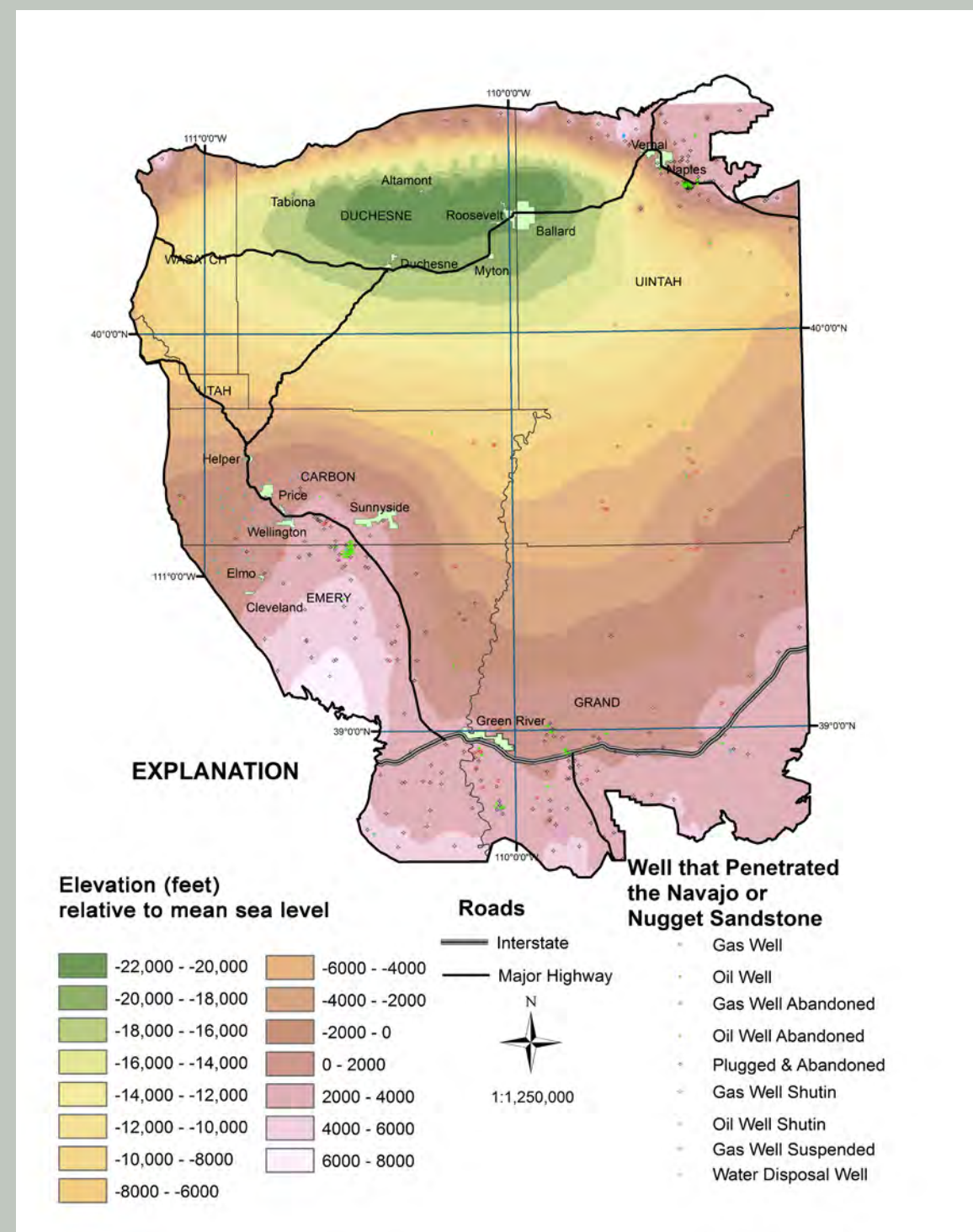
Produced water and formation fracturing flow-back fluids are increasingly reused by companies operating in the Uinta Basin. For example at Natural Buttes gas field, Anadarko Petroleum presently reuses about 90% of the formation fracturing flow-back fluids in subsequent fracturing operations, so it only needs to use fresh water for 10% of its formation fracturing needs, a savings of several million gallons of fresh water per year. Meanwhile at Natural Buttes field in 2013, over 24 million bbls of produced water was disposed in evaporation pits or disposal wells.

At Monument Butte oil field, Newfield Exploration uses most of its produced water for enhanced-oil recovery via water flooding. However, Monument Butte oil field only produced 8 million bbls of water in 2012, but used 22 million bbls for water flooding, requiring 14 million bbls of fresh water use. Perhaps in the near future, Uinta Basin gas fields, rather than disposing of produced water, could provide that water to nearby oil fields that need more water for enhanced-oil recovery operations. Such cooperation could: 1) reduce water disposal well needs at Uinta Basin gas fields, 2) provide a beneficial use for water from gas fields, and 3) reduce fresh water consumption at Uinta Basin oil fields.

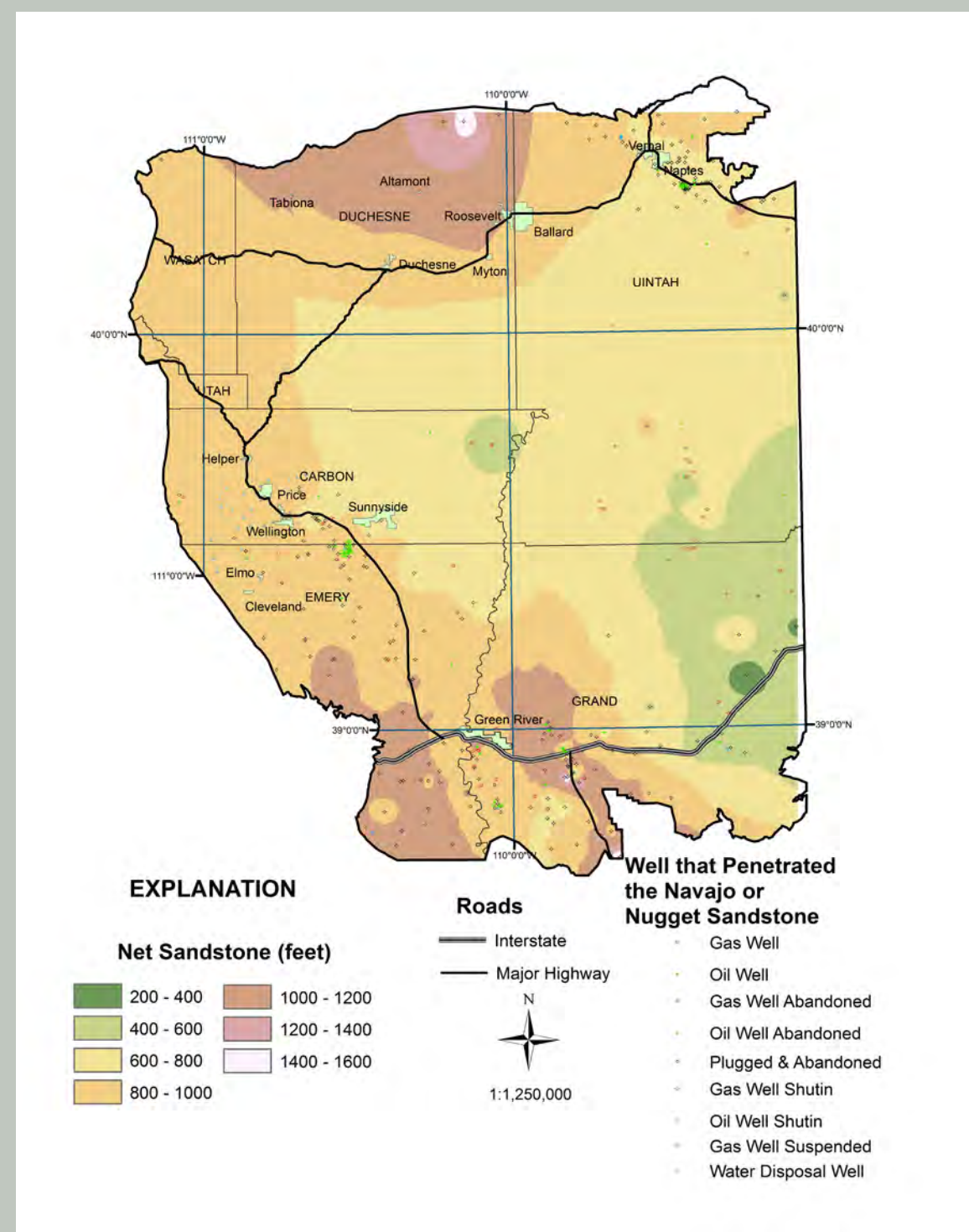
## Jurassic Navajo/Nugget Sandstone



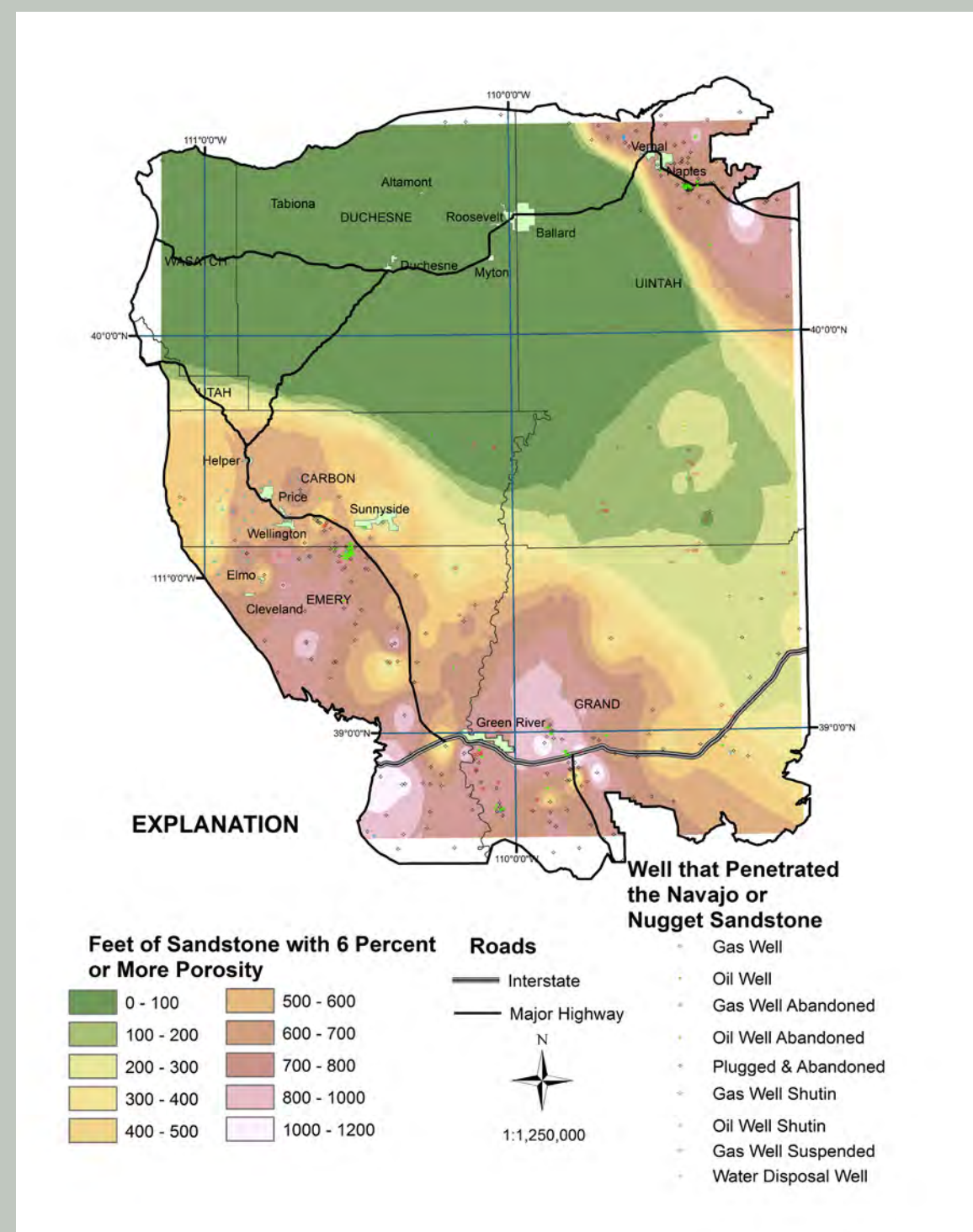
Eolian Cross-Bedded Navajo Sandstone, Northern San Rafael Swell, East-Central Utah



Structure on Top of the Navajo/Nugget Sandstone



Net Sand Thickness (Feet) in the Navajo/Nugget Sandstone

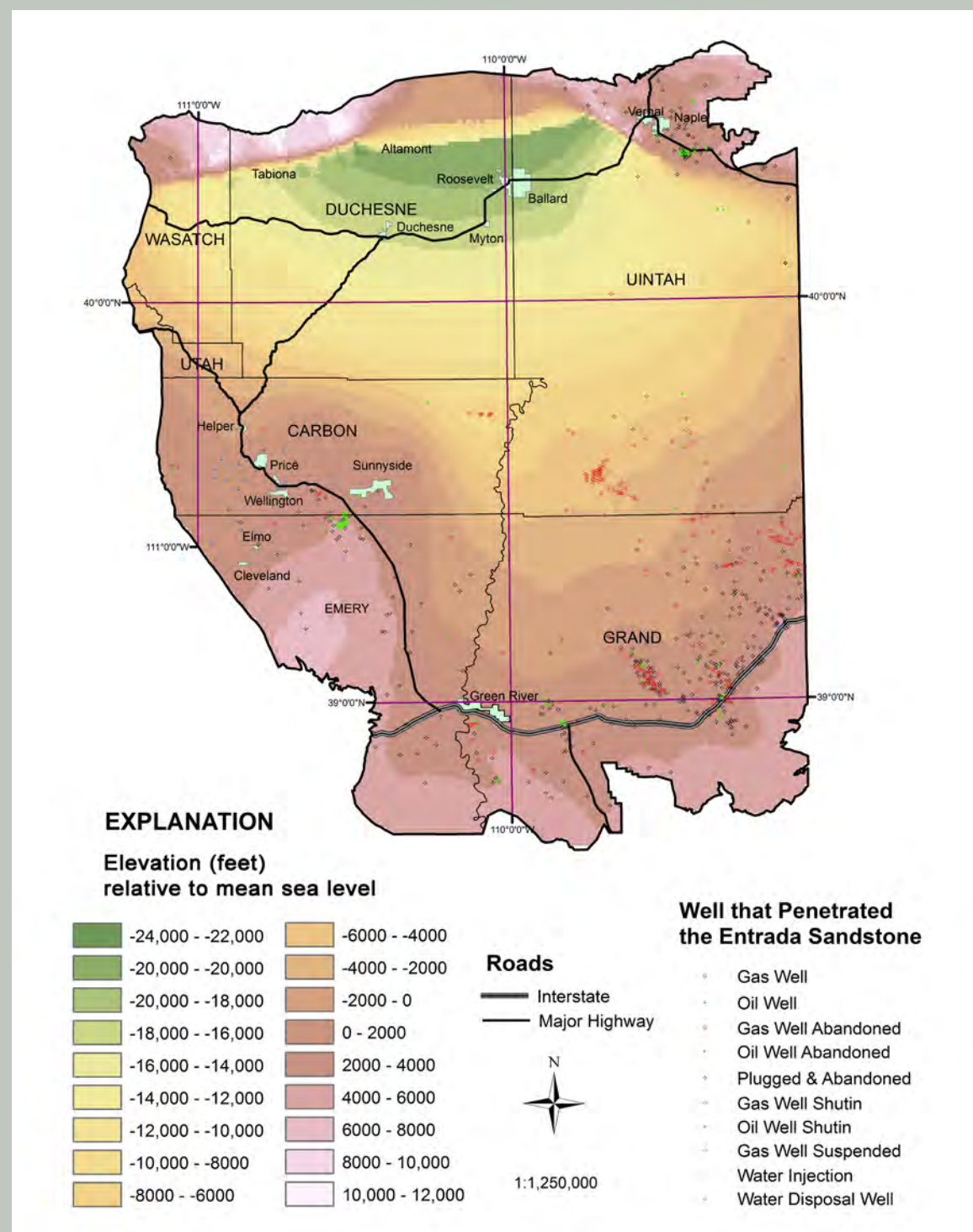


Feet of Navajo/Nugget Sandstone with 6% or More Porosity

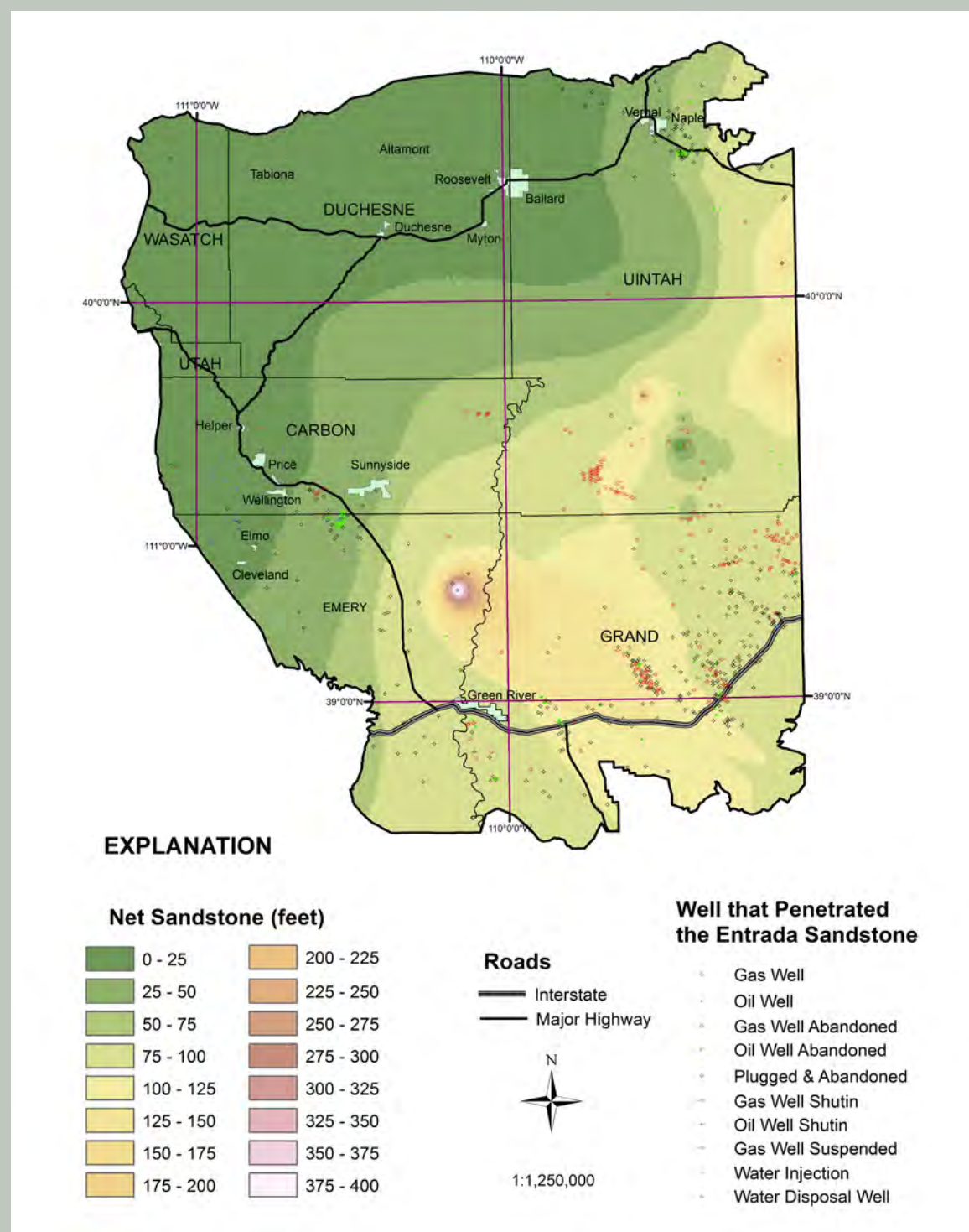
## Jurassic Entrada Sandstone



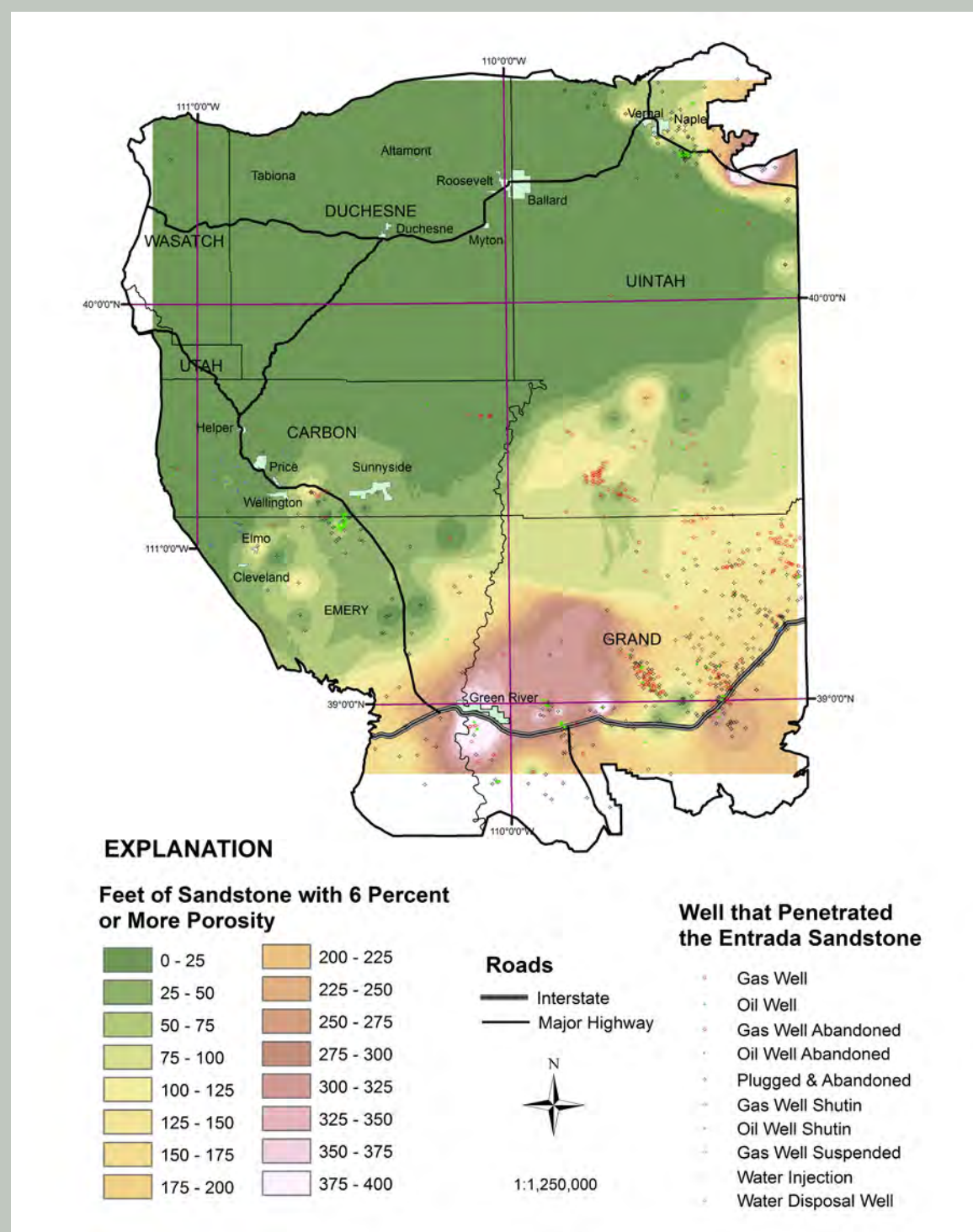
Intertidal to Supratidal Entrada Sandstone, West Flank, San Rafael Swell, East-Central Utah



Structure on Top of the Entrada Sandstone



Net Sand Thickness (Feet) in the Entrada Sandstone

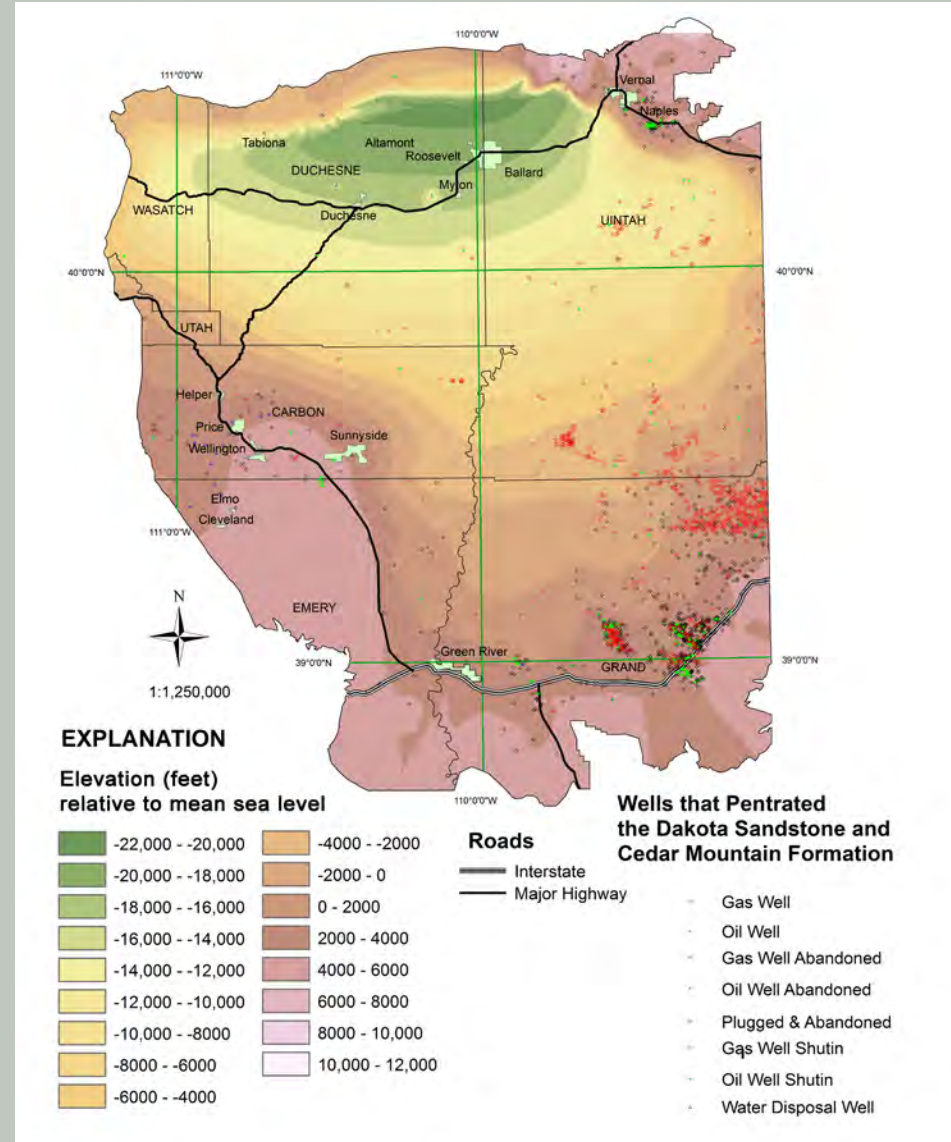


Feet of Entrada Sandstone with 6% or More Porosity

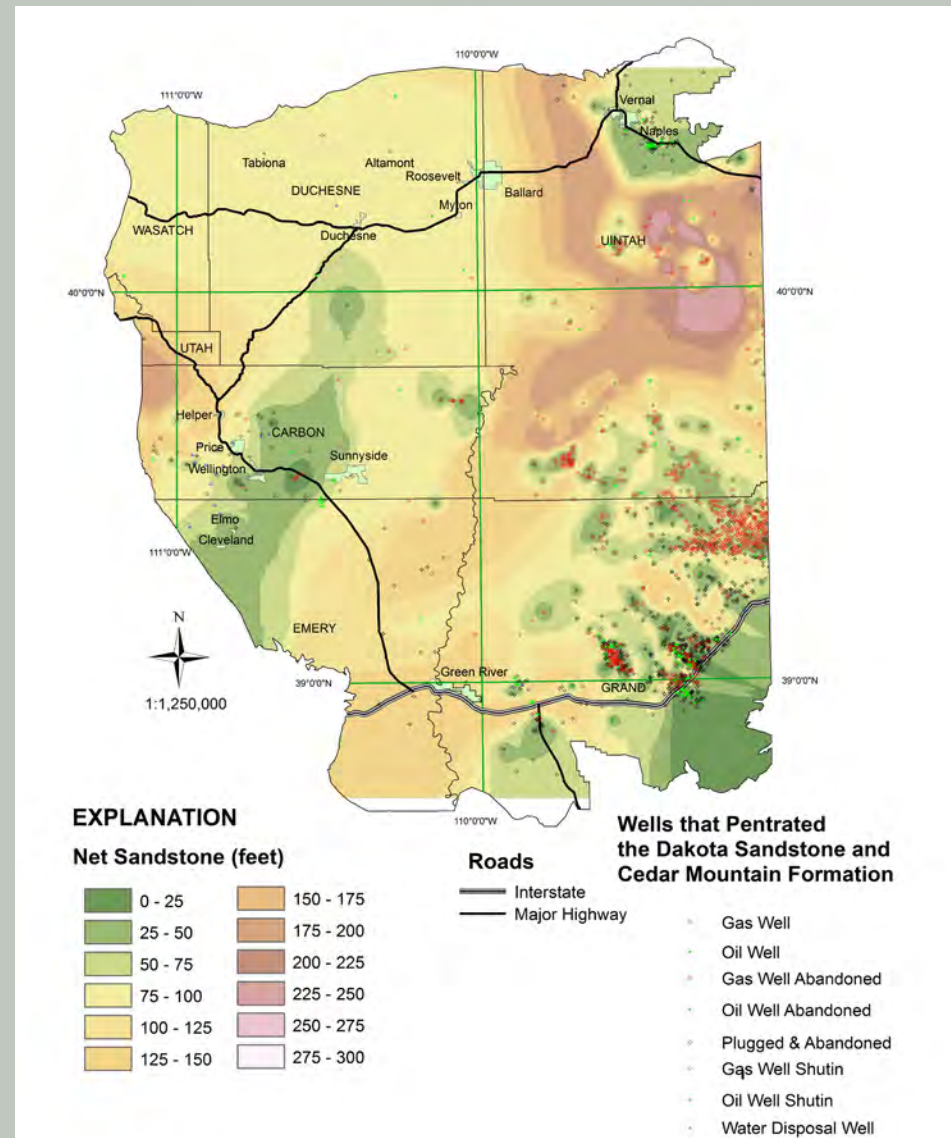
## Cretaceous Cedar Mountain Formation and Dakota Sandstone



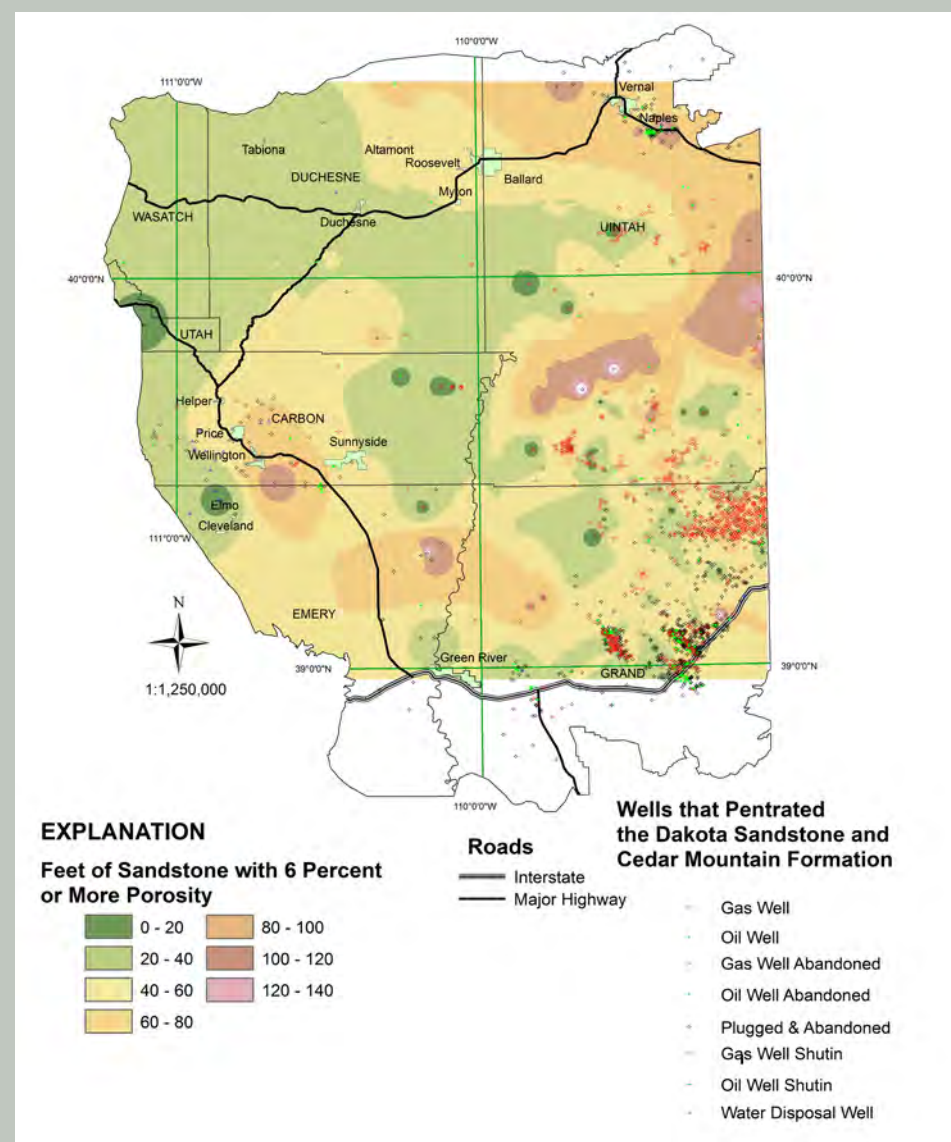
Marginal Marine to Coastal Plain Dakota Sandstone, West Flank, San Rafael Swell, East-Central Utah



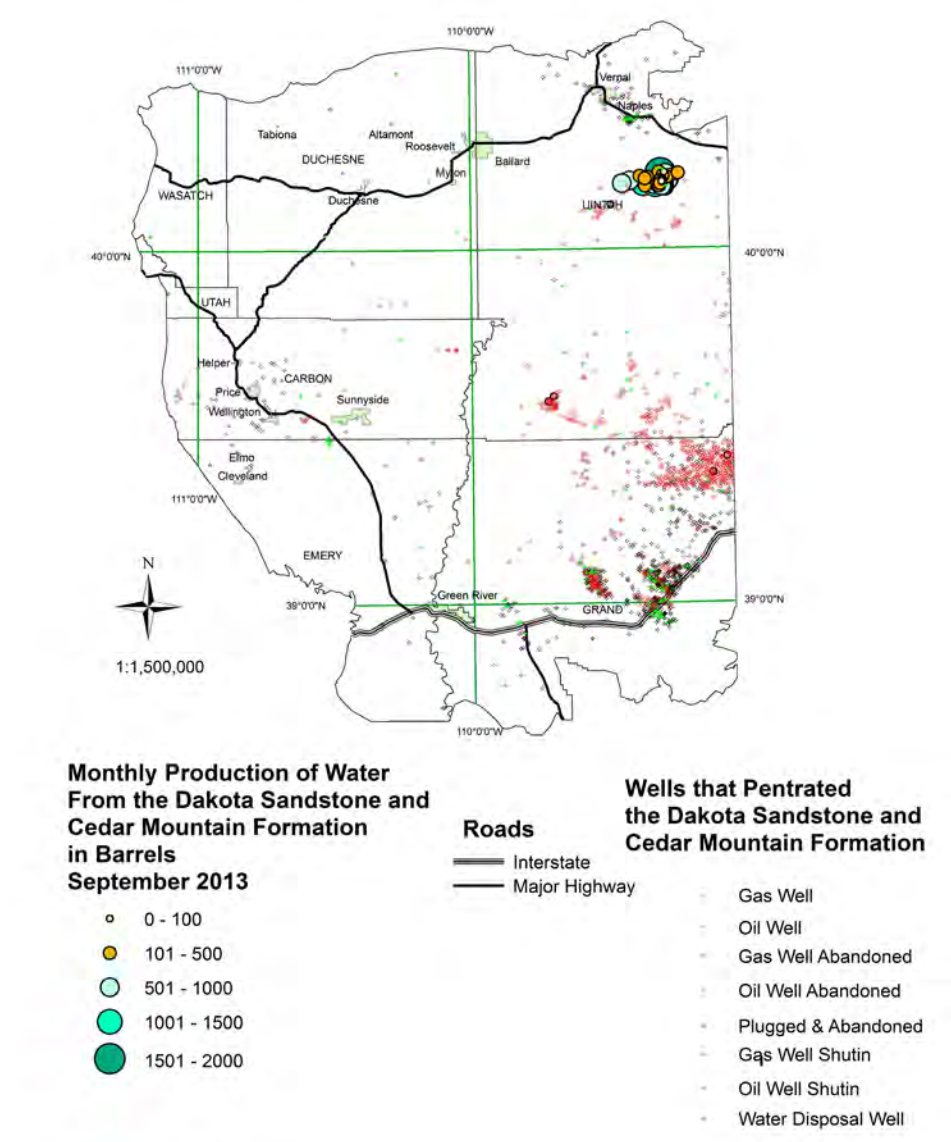
Structure on Top of the Dakota Sandstone



Net Sand Thickness (Feet) in the Dakota Sandstone and Cedar Mountain Formation



Feet of Dakota Sandstone and Cedar Mountain Formation with 6% or More Porosity

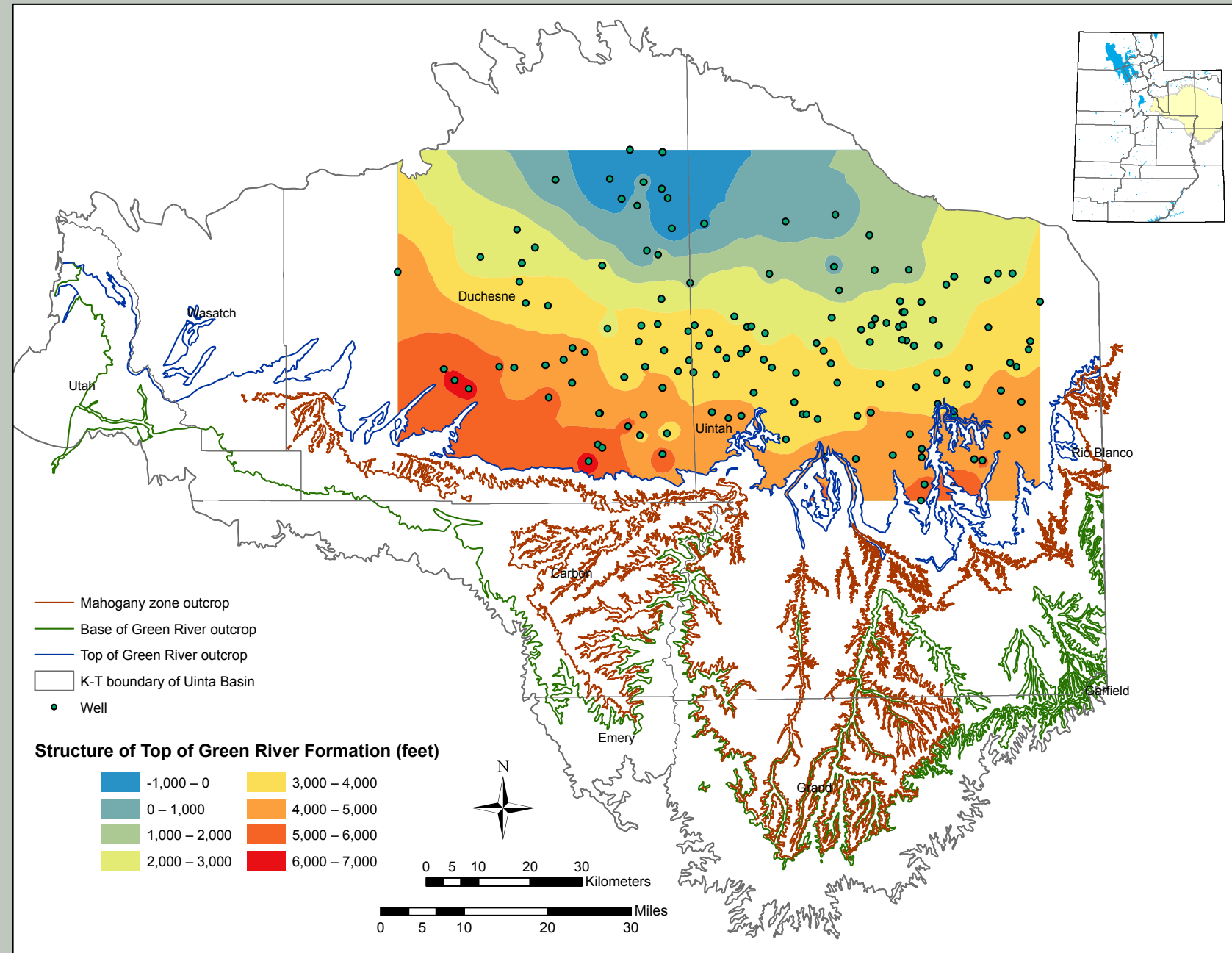


Monthly Production (bbls) of Water from Dakota Sandstone and Cedar Mountain Formation

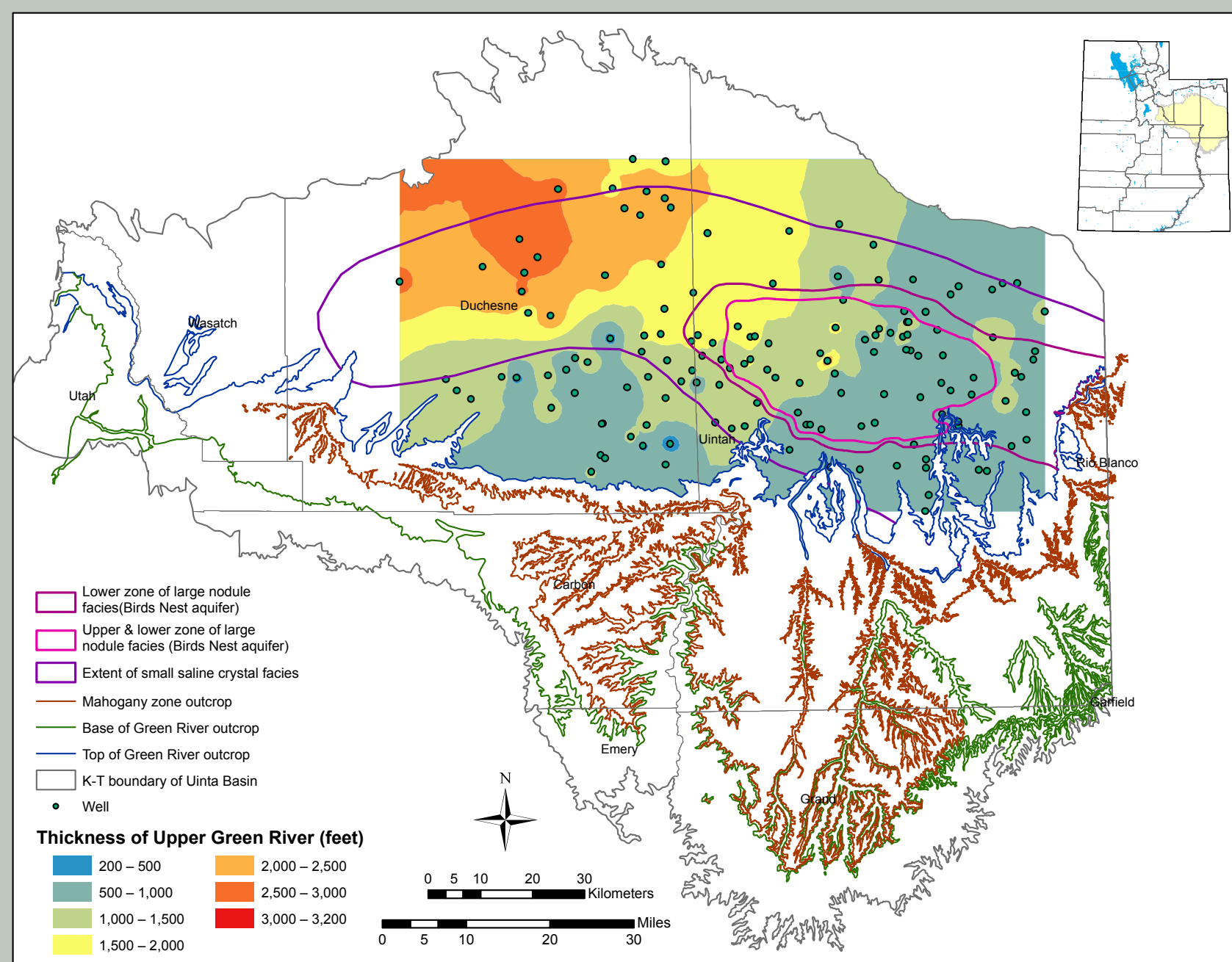
## Tertiary (Eocene) Green River Formation



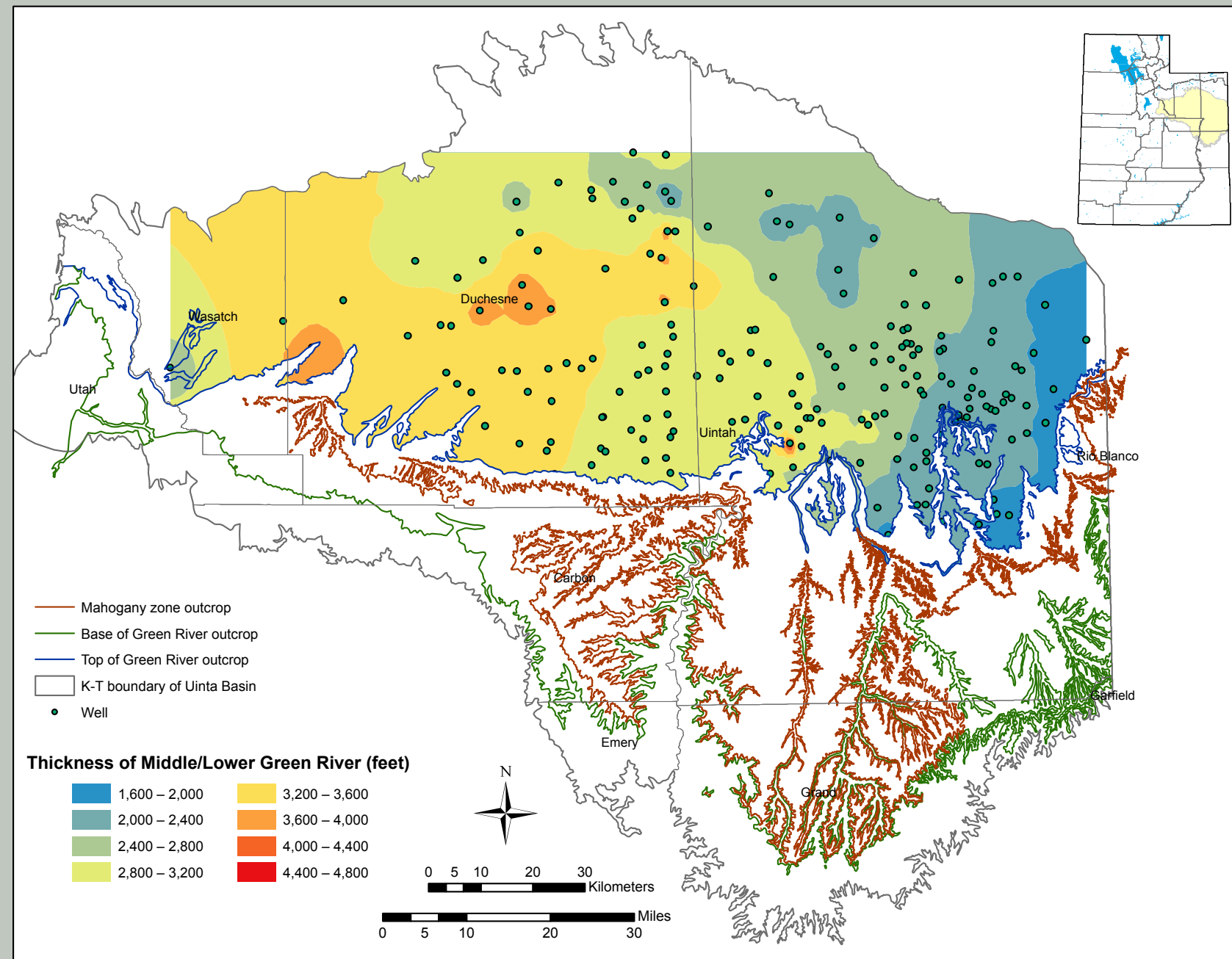
Lacustrine Green River Formation, Nine Mile Canyon, Uinta Basin



Structure on Top of the Green River Formation



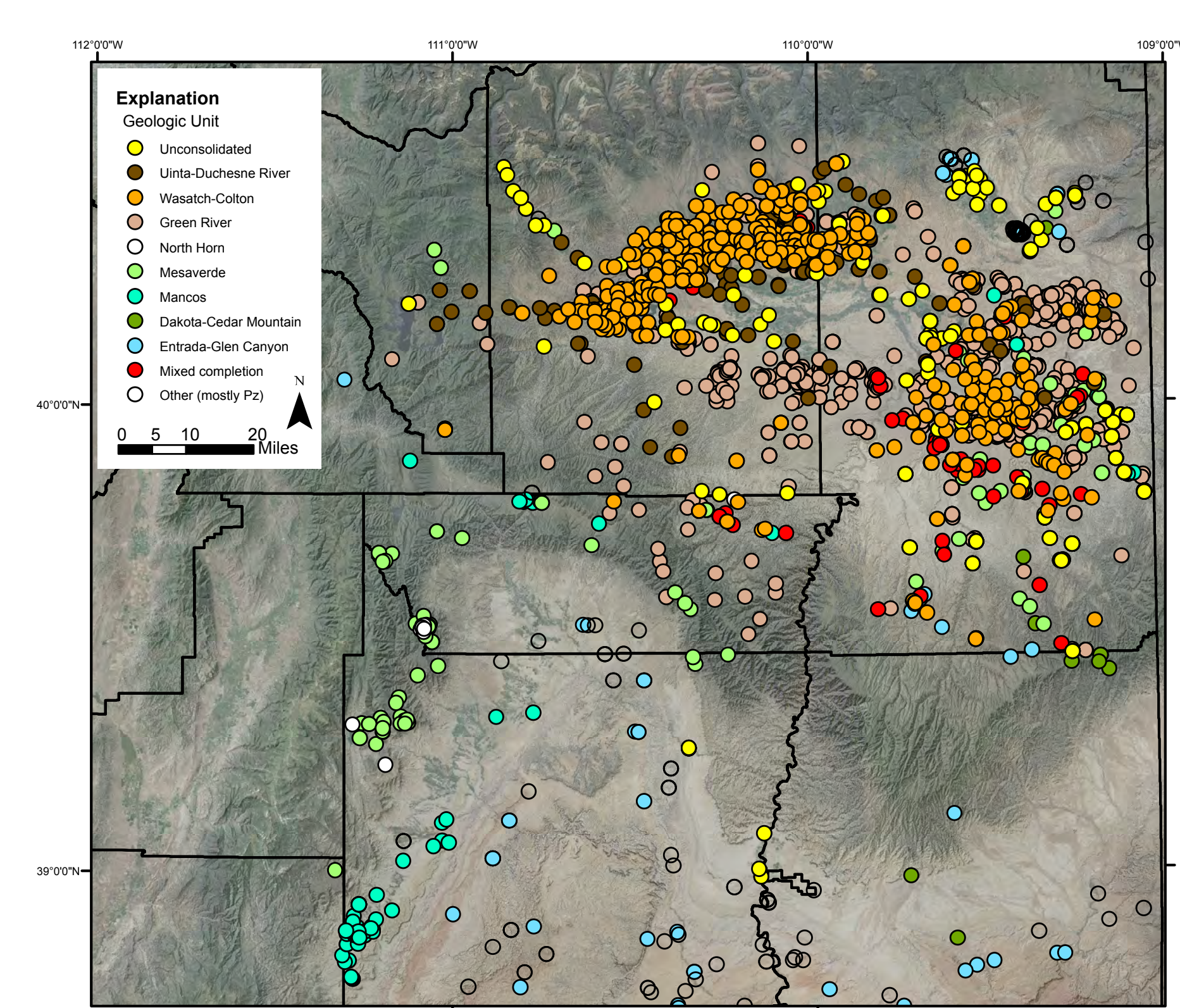
Isopach Map of the Upper Green River Formation



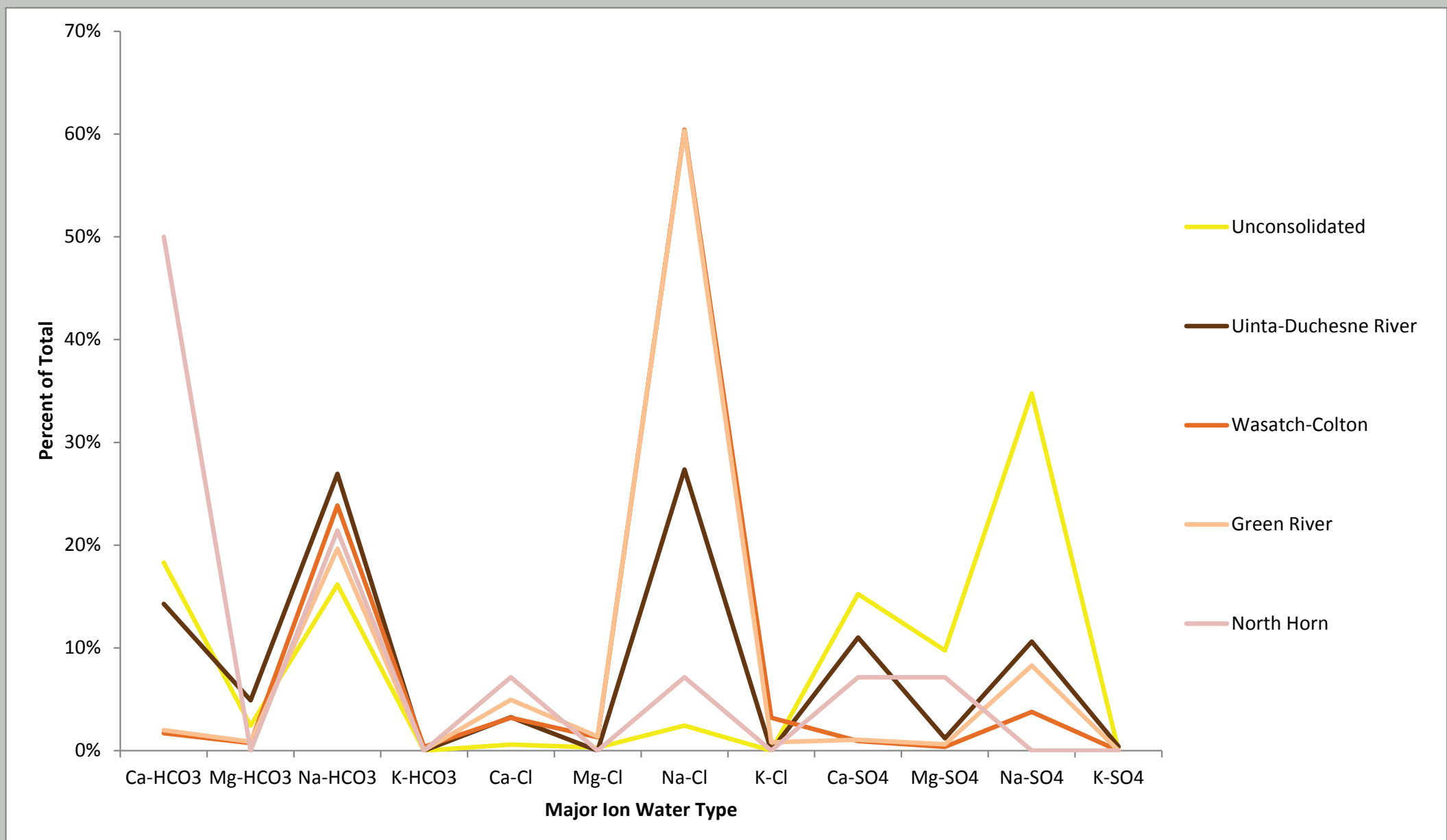
Isopach Map of the Lower to Middle Green River Formation

## PRODUCED WATER GEOCHEMISTRY

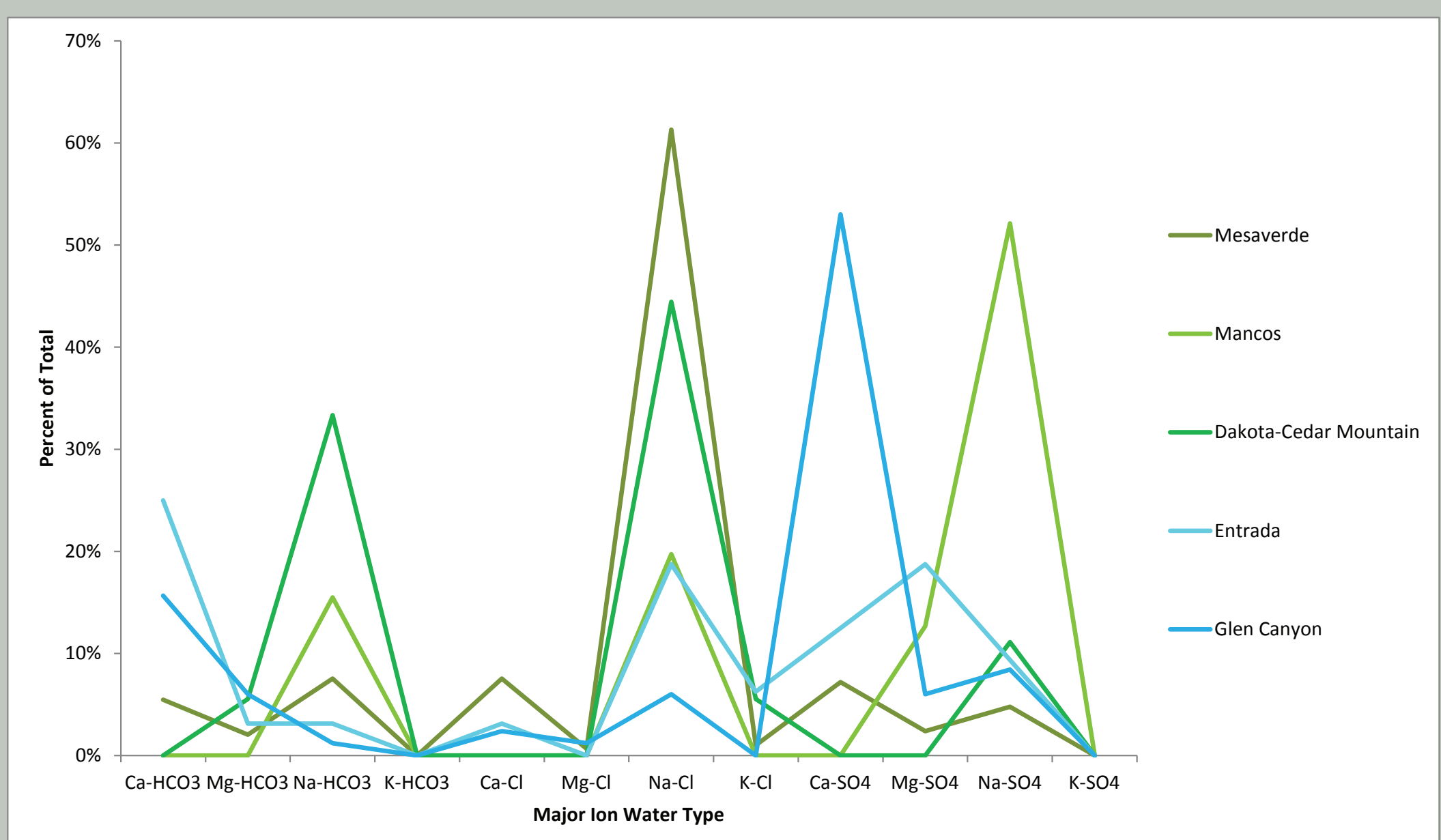
Map of Compiled Water Chemistry Samples for Selected Geologic Units, Uinta Basin and Adjacent Areas



Summary of Major Ion Water Types for Younger Units



Summary of Major Ion Water Types for Older Units



Stratigraphic Column with Number of Water Analyses by Geologic Unit

		Number of Water Analyses	
	Alluvium & other surficial deposits	0-100	347
Eocene	Uinta Formation	1300	112
	Green River Fm	2100	2051
	Parachute Creek Member	1200	
	Douglas Creek Member	900	
Paleo	Wasatch Formation	3200	624
	Mesaverde Group	2100	297
Cretaceous	Costillate Sandstone	380	73
	Mancos Shale	4500	
	Frontier Formation	100	
	Mowry Shale	40	
Jurassic	Dakota & Cedar Mtn Fm	250	18
	Morrison Formation	600	6
	Stump Fm	200	
	Entrada Sandstone	150	34
	Navajo Sandstone	120	95

## Discussion

Over 3600 water quality analyses are available from oil and gas wells and springs in and around the Uinta Basin, and various units have distinct water quality. More than half of the water analyses (2051) are from the most prolific producing reservoir, the Green River Formation. The Green River is primarily a Na-Cl type water (60%), as is the water from the Wasatch-Colton Formations, which has the second largest population of water analyses (624). Both of these formations have a fairly widespread distribution of water analysis sample points, which should allow for basin-wide mapping of their water quality. The Mesaverde Group and Uinta Formation are not produced for hydrocarbons as widely as the first two units mentioned, and thus have correspondingly fewer water analyses (297 and 117, respectively). Some regional quality trends may be discernable from the Mesaverde and Uinta data. Over 340 water analyses, varied but predominantly Na-SO<sub>4</sub> type water, are available from alluvial and other non-consolidated deposits, but the rapid lateral lithologic variation and heterogeneity of these deposits may make discerning water quality trends difficult. The other geologic reservoir/aquifer units being mapped in the Uinta Basin generally have less than 100 water quality analyses apiece, and it is likely that only local water quality trends may be discernable with the limited data from these poorly sampled units.